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The Effect of Spelling with User's Mother Tongue on P300 Speller Performance

Leena A. Alhajjaj[1], Sarah S. Alrumiah[1], Jowharah F. Alshobaili[1] and Dina M. Ibrahim[1,2]

[1]*Department of Information Technology, College of Computer, Qassim University, Buraydah, Saudi Arabia.*

[2]*Computers and Control Engineering Department, Faculty of Engineering, Tanta University, Egypt.*

(ORCID: 0000-0001-8697-919X, 0000-0003-4313-1652, 0000-0001-8416-4499, 0000-0002-7775-05772)

Abstract

P300 speller is a Brain-Computer Interface (BCI) technology that helps people with neuromuscular disabilities communicating with the world using their brain signals. Based on the sensitivity of this process, many factors could affect its performance. As a result, this effort studied the effect of spelling with user's mother tongue on the spelling performance. Two healthy native Arabic participants experienced in our study that was developed using BCI2000. The spelling process of the visual single-layer P300 speller has been done with two spellers: Arabic and English, using Row-Column (RC) flashing pattern. A dataset of 14 words in both languages, i.e. the total of 28 terms, was given to be spelt. Each participant spelt each word in two sessions with ten flashes per session, i.e. the total of 112 sessions. The results seem to be affected by the length of the word regardless of the spelling language, e.g. spelling"حب " will achieve high accuracy faster than spelling" Love". The study concluded that the length of the word might be the main factor that may affect spelling performance.

Keywords: Brain-Computer Interface (BCI), P300 speller, Speller language, mother tongue, spelling performance.

I. INTRODUCTION

According to the World Health Organization (WHO), there are more than two million suffering from some kind of disabilities, representing relatively 37% of the population [1]. Due to this unfortunate fact, they are facing difficulties in their communication. Hence, the concept of Brain-Computer Interface (BCI) established, which engage them with society by providing an alternative communication channel [2]. The structure of any BCI system starts with acquiring brain signals by the electrodes on human scalp, skull or within the human brain, then these signals are processed to extract desired features which consider as user's intents [2,3]. Then these features will be translated to execute a specific action.

Moreover, BCI classified in two classes, dependent and independent systems [4]. Independent BCI systems depends on the patient's intent, i.e. attention, by detecting brain signals in the form of P300 Event-Related Potential (ERB). On the other hand, BCI systems can be classified based on the device position to, invasive, semi-invasive, and non-invasive. Researchers continued their efforts enriching it with many applications, such as BCI spellers that allow patients to communicate through their brain signals. There are a variety of BCI spellers; most of them use Electroencephalogram (EEG) signals, which is one of the tools to record brain waves activity by placing electrodes on the patient scalp [5].

BCI spellers are used to spell words based on BCI technology [2]. P300 speller is an independent BCI speller that detects the target, i.e. desired character, relying on the positive-going wave with a latency about 300 milliseconds (ms) after it flashes. The spelling process starts with wearing an EEG device while presenting a matrix of characters on the screen. The characters will randomly flash in a specific pattern, i.e. Row-Column (RC) [6], Single-Character (SC) [6], or Region-Based (RB) [7] flashing patterns. Each character will flash with a specific number of flashes. Whenever the desired character flashes, a P300 will be detected in the user brain activity. The repetition of this appearance will recognize the system with the target that will be displayed in the feedback bar. Researchers put their efforts on developing this technology in different mediums, audio [8], visual [2], [7-17], audio-visual P300 spellers [18,19]. Studies continue to enhance the spelling performance by changing the speller style, matrix size, or adding layers, e.g. uni-modal [2], [9-15], bi-modal [7,16], multimodal [17] spellers.

Most of the previous studies focus their attention on increasing the accuracy rate of P300 speller. Although high accuracy increases the performance of P300 speller, it increases the spelling duration. Furthermore, time-consuming spelling process results in poor speller usability. We have not seen any study that shows how will be the effect of spelling with user's mother tongue on the spelling accuracy and duration. Thus, we decided to study the impact of spelling with user's mother tongue on the spelling performance using two languages, Arabic and English spellers.

The following sections will illustrate the followed methodology, the study's results, as well as the concluded findings.

II. MATERIALS AND METHODS

This study aims to find how the spelling performance would be affected by spelling with Arabic and English spellers with native Arabic speakers. The research question is: Does spelling with user's mother tongue affect the spelling performance? If so, then how?

1. Participants

Two healthy Arabic speaker participants experienced this study, both were females with some BCI theoretical

background. These participants are Leena and Sarah, the first and second authors in this study, and intend to conduct the experiment on themselves as a self-experimentation. they understood that studying is research on human subjects. They volunteered to do this experiment.

2. Data Acquisition

We used Emotiv Epoc flex EEG headset that covers Fz, Cz, Pz, P3, P4, P7, P8, and Oz brain channels. Brian signals where processed using BCI2000 software, which is an open-source software that supports different data acquisition devices. We installed BCI2000 on Windows-64bits operating system.

3. BCI2000 P300 speller setup

We constructed two P300 spellers using BCI2000 software. Thus, to perform custom P300 speller experiments, we need to modify some of the parameters. With the P300 speller configuration window, we were able to change some of the default parameters related to source, storage, filtering, and application settings. In the source tab, the hardware settings are changed based on the EEG device used [20]. After configuring the source settings, we started making the needed configurations for the storage, filtering, and application setting.

Each time we run any experiment, we applied some modifications in the storage settings based on the participant name and session number. As the spelling duration in BCI2000 P300 speller depends on the number of flashes a letter flashes in a single run. We attempted to use ten flashes to figure out at which flash the word will be spelt correctly. We assumed that ten flashes would be enough to spell a word without slowing down the spelling process.

4. Paradigms design

BCI2000 allows users to make visual and audio-visual paradigms, as well as replacing letters with words, icons, etc. Users are able to make many paradigm design alterations. In this project, we made some modification on the speller matrix in order to make Arabic and English spellers. Fig. 1 shows the structure of the P300 speller matrix, i.e. the order of letters' placement, and our English and Arabic matrices generations.

5. Experiment process

Before each spelling session, the authors place the device on the participant's head and check its connection. An instruction guide that contained the experiment process was given to them to be prepared. We also gave the participants a 14 words dataset displayed in Table 1 that we assume are the most known and frequently used words in Saudi Arabia. We also kept in mind that all these words in both languages are known to the participants.

Participants went through 56 experiments each, 28 of them were spelt with an Arabic speller, while the rest with an English speller. They ended up with 112 experiments. Each participant has spelt each word in the dataset, in two runs, i.e. two sessions. To be more accurate, the experiments were done in the same environments. Experiencing our P300 speller follows the calibration session as illustrated in Fig. 2. The results were classified using P300 classifier tool.

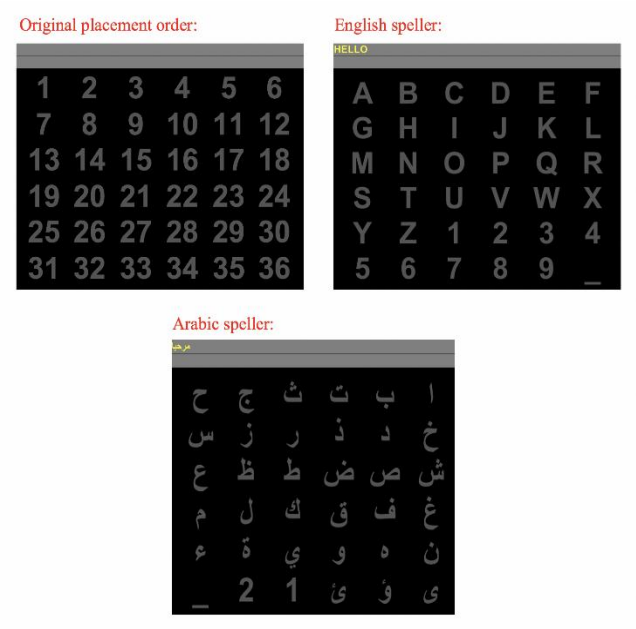


Fig. 1. The structure of the P300 speller matrix.

Table 1: Experiment Dataset.

Seq.	Word in Arabic	Word in English
1	نعم	Yes
2	لا	No
3	شكرا	Thank you
4	عفوا	Welcome
5	سلام	Peace
6	رجاء	Please
7	حب	Love
8	مرحبا	Hello
9	مع السلامة	Goodbye
10	سعودي	Saudi
11	اسف	Sorry
12	نساء	Women
13	قيادة	Drive
14	صباح الخير	Good morning

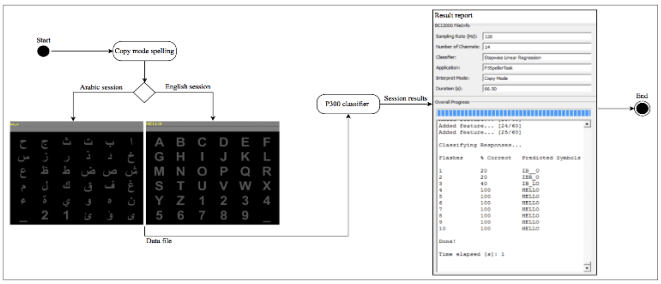


Fig. 2. The experiment process began with a copy mode spelling which its results are saved as a data file that will be classified in the P300 classifier tool which reports the spelling results.

III. RESULTS

The result of the 112 experiments was beyond expectations. Table 2 was constructed that illustrates the average accuracy and average flash number for each word. As participants experienced spelling with ten flashes for each letter, the result of P300 classifier reported ten accuracies for each flash in a single session. Hence, we picked the first occurrence of the highest accuracy from that report with its number of flashes, as explained in Fig. 3. Then we calculated the average accuracy and flash number for the two sessions which were applied for each word. Table 3 represents the overall results of the average accuracy and flash number for the Arabic and English words.

Table 2: Experiment Results.

		P1		P2	
		Accuracy (%)	Flashes needed	Accuracy (%)	Flashes needed
Arabic words	نعم	100	4	100	3
	لا	100	2	100	1
	شكرا	100	4	100	4
	عفوا	100	5	100	7
	سلام	100	4	100	4
	رجاء	87.5	5	100	7
	حب	100	3	100	2
	مرحبا	90	8	100	6
	مع السلامة	85	8	75	8
	سعودي	100	6	100	7
	اسف	100	2	100	5
	نساء	100	6	100	5
	قيادة	100	6	100	6
	صباح الخير	75	9	70	10
Average		94	6	96	6
English words	Yes	100	3	100	3
	No	100	1	100	2
	Thank you	72.5	10	83.5	7
	Welcome	100	8	93	8
	Peace	70	10	100	4
	Please	100	8	91.5	7
	Love	100	5	100	5
	Hello	100	5	100	6
	Goodbye	93	8	93	6
	Saudi	100	5	100	4
	Sorry	90	8	100	7
	Women	100	8	100	6
	Drive	100	7	90	7
	Good morning	79	8	70.5	10
Average		93	7	94	6

```
Classifying Responses...

Flashes     % Correct   Predicted Symbols

1           0           19JQ7
2           20          ZEJOI
3           20          ZEIOM
4           60          HELOM
5           80          HELOO
6           100         HELLO
7           100         HELLO
8           100         HELLO
9           100         HELLO
10          100         HELLO

Done!

Time elapsed [s]: 1
```

Fig. 3. P300 classifier report: Choosing the first highest accuracy occurrence for each run.

The results showed that the spelling accuracy in user's mother language is higher and faster than the foreign language. However, that results may be affected by the words length, so we divided the words into groups. The groups are constructed based on the mean of the total letters of the 28 words, i.e. 14 Arabic words and their corresponding English terms. (a) Words have a length less than 5 (mean value), (b) five letters words, and (c) words with length greater than 5. Table 4 shows the number of flashes and their accuracies for each group. The analyses illustrate that word's length has a significant impact on spelling performance, regardless the language used.

Table 3: Overall Result.

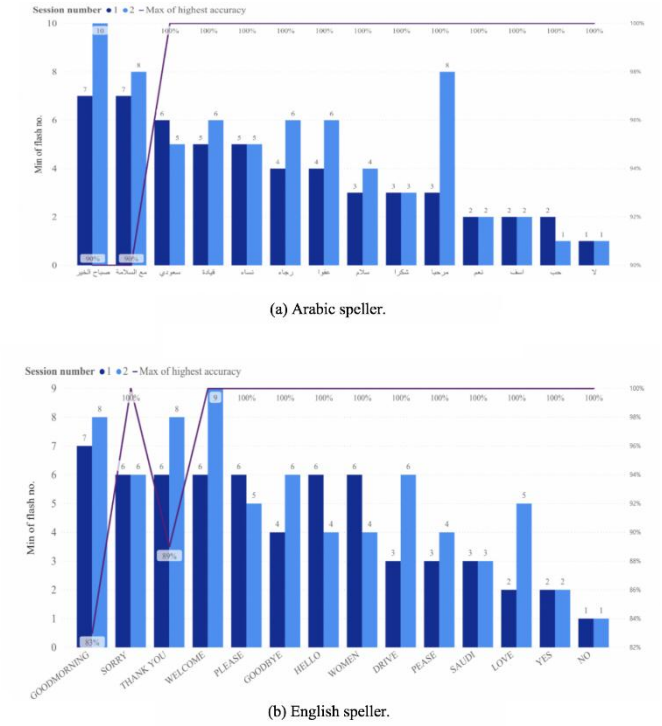
	Accuracy (%)	Flashes needed
Arabic (users' mother tongue)	95	6
English	93.5	6.5

Results analyses are needed to compare between the two languages and sessions. Data visualization were made using Power BI tool. Many cases were made to identify the relationship between the factors: words length, accuracies achieved, speller language, and number of flashes needed, that may affect spelling performance.

Table 4: The effect of words length on the spelling results.

Arabic words			**English words**		
Word	**Flash no.**	**Accuracy (%)**	**Word**	**Flash no.**	**Accuracy (%)**
Words' length < 5					
لا	2	100	No	2	100
نعم	4	100	Yes	3	100
حب	3	100	Love	5	100
اسف	4	100			
رجاء	6	93.8			
سلام	4	100			
شكرا	4	100			
عفوا	6	100			
نساء	6	100			
Overall	5	99.3		4	100
Words' length = 5					
قيادة	6	100	Drive	7	95
مرحبا	7	95	Hello	6	100
سعودي	7	100	Saudi	5	100
			Peace	7	85
			Sorry	8	95
			Women	7	100
Overall	7	98.3		7	95.8
Words' length > 5					
صباح الخير	10	72.5	Good morning	9	74.8
مع السلامة	8	80	Goodbye	7	93
			Please	8	95.75
			Welcome	8	96.5
			Thank you	9	78
Overall	9	76.25		9	87.61

- Case 1: The effect of the speller's language on the spelling performance. Fig. 4 shows the minimum number of flashes for each word, as well as the maximum accuracy achieved. We observed that the speller language does not impact the spelling performance. Thus, as mentioned previously, the length of the word influences the spelling performance.



(a) Arabic speller.

(b) English speller.

Fig. 4. The maximum accuracy achieved for each word with its minimum number of flashes.

- Case 2: The effective number of flashes in the spelling performance. Fig. 5 counts the flash occurrences in our results and shows that six flashes were the mode of flash numbers, and it may be the effective number of flashes to spell with. It also illustrates that few words had to be spelt with more than 6 flashes which maybe refer to word's length or the user attention, as it begins with high attention that reduces over time based on participants' feedback.

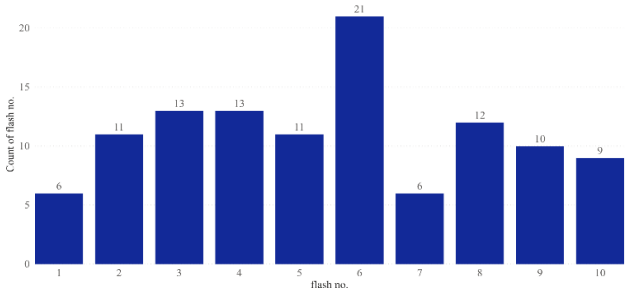
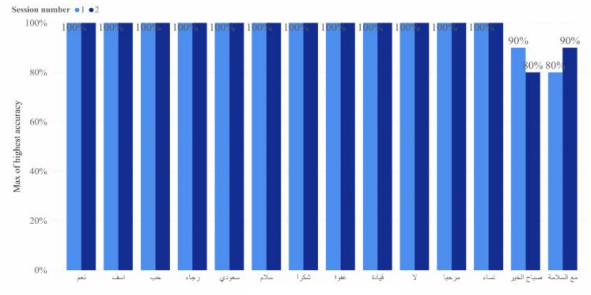
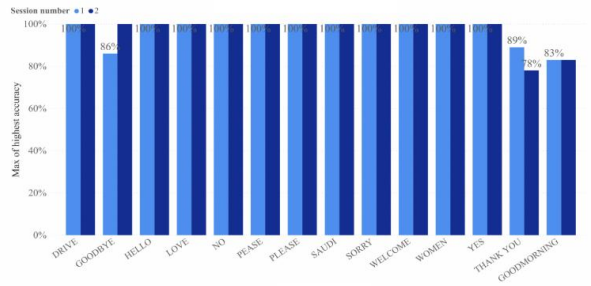


Fig. 5. Counts of flash occurrences in the results.

- Case 3: The relationship between the number of sessions applied, its maximum accuracies achieved, and the speller's language, Fig. 6 illustrates the maximum accuracy of each word in each session. As the charts show that the accuracies in the first and second session are approximately identical.



(a) Arabic speller.



(b) English speller.

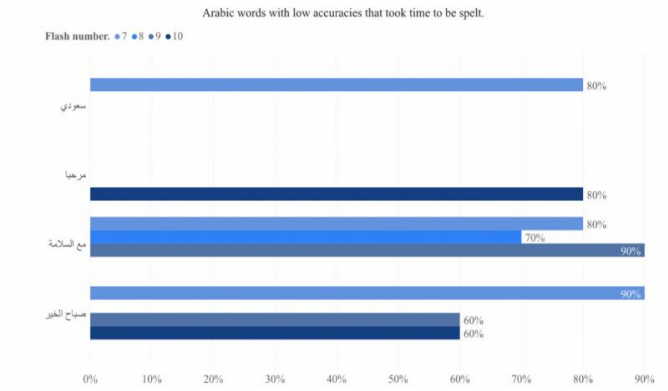
Fig. 6. The maximum accuracy of each word in each session.

- Case 4: All words with accuracies lower than 100\% and a flash number greater than 6, i.e. the mode number of flashes in the results of the experiments. Fig. 7 presents these words and their accuracies, as well as their flash numbers. As a result, increasing the number of flashes increases the spelling duration; in addition, low accuracies were achieved, result in a slow and exhausted spelling process.

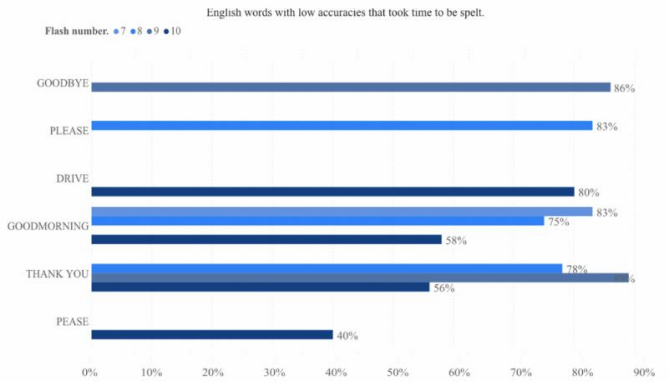
IV. DISCUSSION

In this section, we highlight the significant findings we observed during this study that we believe it has some effect on the results. The following points explain these findings:

The effect of the language on the spelling performance: Our dataset contains Arabic and English words to test if the language of the speller impacts spelling performance. After analyzing the results, we conclude that the speller language does not affect spelling performance. The performance is affected by the words' length.



(a) Arabic speller.



(b) English speller.

Fig. 7. Words that took more than 6 flashes to be spelt.

The relationship between the word's length and the spelling accuracy: The length of the word, whether long or short performs a huge impact on spelling accuracy. We have been noticing that the longer the spelt word be, the lower the accuracy rate achieved. Besides, short terms, e.g. no, yes, and love, recorded higher accuracy rates with few numbers of flashes.

The effect of the number of flashes on the spelling speed: One of the noticeable points is the number of flashes per session, which plays a major role in accelerating the spelling process. Users have to select the right number of flashes to get good performance and avoid losing patient attention.

The repeated session and the accuracy of the spelling performance: We have repeated the spelling process for each word twice, i.e. two sessions were made for each word, to examine whether the number of sessions has any impact on the spelling performance. However, we observed that repeating the spelling of a word does not affect the performance as the results above show. In some cases, the first session had better accuracy, while some had higher accuracy in the second session, and in some cases, the results for both sessions were equal.

V. CONCLUSION

P300 speller technology lights up people's way by providing an alternative form of communication, especially with neuromuscular disabilities. It translates user attention in the brain wave signals to spell words and make sentences. Moreover, the primary purpose of this study was to investigate the efficiency of P300 speller performance under some circumstances, e.g. using a foreign language, and spell words in different lengths. According to our results, we found that the word's length has a major influence on spelling performance. Short words would be spelt faster than long words, e.g. no, yes. Whereas using user's mother language on the speller would not impact the performance, i.e. words familiarity may not speed up the spelling process.

Studying and experiencing one of the BCI applications to communicates with neuromuscular disability' patients was one of our goals. After experiencing and testing P300 speller with healthy people, we believe it will be effective with neuromuscular disability patients as we plan in the near future to test it on them. Furthermore, the results of this study will open alternative ways of thinking in developing the performance of P300 spellers.

Due to circumstances beyond our control (COVID-19), we forced to do the experiment on a small number of participants. Thus, we plan to do the same experiment with involving more participants with different language background, to test the outcomes accurately. Then we will test this study on patients with neuromuscular disabilities. After that, we will work on enhancing the spelling performance by designing new paradigms that balance between the spelling duration and results' accuracy.

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